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## Postoperative Complication Burden, Revision Risk, and Health Care Use in Obese Patients Undergoing Primary Adult Thoracolumbar Deformity Surgery

Varshneya, Kunal ; Pangal, Dhiraj J ; Stienen, Martin N ; Ho, Allen L ; Fatemi, Parastou ; Medress, Zachary A ; Herrick, Daniel B ; Desai, Atman ; Ratliff, John K ; Veeravagu, Anand

**Abstract:** Study Design: This is a retrospective cohort study using a nationally representative administrative database. Objective: To identify the impact of obesity on postoperative outcomes in patients undergoing thoracolumbar adult spinal deformity (ASD) surgery. Background: The obesity rate in the United States remains staggering, with approximately one-third of all Americans being overweight or obese. However, the impact of elevated body mass index on spine surgery outcomes remains unclear. Methods: We queried the MarketScan database to identify patients who were diagnosed with a spinal deformity and underwent ASD surgery from 2007 to 2016. Patients were then stratified by whether or not they were diagnosed as obese at index surgical admission. Propensity score matching (PSM) was then utilized to mitigate intergroup differences between obese and nonobese patients. Patients <18 years and those with any prior history of trauma or tumor were excluded from this study. Baseline demographics and comorbidities, postoperative complication rates, and short- and long-term reoperation rates were determined. Results: A total of 7423 patients met the inclusion criteria of this study, of whom 597 (8.0%) were obese. Initially, patients with obesity had a higher 90-day postoperative complication rate than nonobese patients (46.1% vs 40.8%,  $P < .05$ ); however, this difference did not remain after PSM. Revision surgery rates after 2 years were similar across the 2 groups following primary surgery (obese, 21.4%, vs nonobese, 22.0%;  $P = .7588$ ). Health care use occurred at a higher rate among obese patients through 2 years of long-term follow-up (obese, 152930, *vs* nonobese, 140 550;  $P < .05$ ). Conclusion: Patients diagnosed with obesity who underwent ASD surgery did not demonstrate increased rates of complications, reoperations, or readmissions. However, overall health care use through 2 years of follow-up after index surgery was higher in the obesity cohort.

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# Postoperative Complication Burden, Revision Risk, and Health Care Use in Obese Patients Undergoing Primary Adult Thoracolumbar Deformity Surgery

Kunal Varshneya, BS<sup>1</sup> , Dhiraj J. Pangal, BS<sup>2</sup>,  
Martin N. Stienen, MD, FEBNS<sup>1,3</sup> , Allen L. Ho, MD<sup>1</sup>,  
Parastou Fatemi, MD<sup>1</sup>, Zachary A. Medress, MD<sup>1</sup>,  
Daniel B. Herrick, MD, PhD<sup>1</sup>, Atman Desai, MD<sup>1</sup>,  
John K. Ratliff, MD<sup>1</sup>, and Anand Veeravagu, MD<sup>1</sup>

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## Abstract

**Study Design:** This is a retrospective cohort study using a nationally representative administrative database.

**Objective:** To identify the impact of obesity on postoperative outcomes in patients undergoing thoracolumbar adult spinal deformity (ASD) surgery.

**Background:** The obesity rate in the United States remains staggering, with approximately one-third of all Americans being overweight or obese. However, the impact of elevated body mass index on spine surgery outcomes remains unclear.

**Methods:** We queried the MarketScan database to identify patients who were diagnosed with a spinal deformity and underwent ASD surgery from 2007 to 2016. Patients were then stratified by whether or not they were diagnosed as obese at index surgical admission. Propensity score matching (PSM) was then utilized to mitigate intergroup differences between obese and nonobese patients. Patients <18 years and those with any prior history of trauma or tumor were excluded from this study. Baseline demographics and comorbidities, postoperative complication rates, and short- and long-term reoperation rates were determined.

**Results:** A total of 7423 patients met the inclusion criteria of this study, of whom 597 (8.0%) were obese. Initially, patients with obesity had a higher 90-day postoperative complication rate than nonobese patients (46.1% vs 40.8%,  $P < .05$ ); however, this difference did not remain after PSM. Revision surgery rates after 2 years were similar across the 2 groups following primary surgery (obese, 21.4%, vs nonobese, 22.0%;  $P = .7588$ ). Health care use occurred at a higher rate among obese patients through 2 years of long-term follow-up (obese, \$152 930, vs nonobese, \$140 550;  $P < .05$ ).

**Conclusion:** Patients diagnosed with obesity who underwent ASD surgery did not demonstrate increased rates of complications, reoperations, or readmissions. However, overall health care use through 2 years of follow-up after index surgery was higher in the obesity cohort.

## Keywords

spine, thoracolumbar, surgery, deformity, obesity

## Introduction

Adult spinal deformity (ASD) is a common pathology, especially among individuals aged 65 years and older, where its prevalence is as high as 65% in some reports.<sup>1-3</sup> ASD includes a broad range of degenerative pathologies that, in the presence

<sup>1</sup> Stanford University School of Medicine, Stanford, CA, USA

<sup>2</sup> Keck School of Medicine, Los Angeles, CA, USA

<sup>3</sup> University of Zurich, Zurich, Switzerland

## Corresponding Author:

Anand Veeravagu, Department of Neurosurgery, Stanford University, 300 Pasteur Drive, Edwards Bldg, R281, Stanford, CA 94305, USA.

Email: Anandv2@stanford.edu



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of sagittal imbalance, can have significant impact on quality of life and overall health outcomes.<sup>4-6</sup> Historically, the treatment of ASD included few surgical options because of the high-risk nature of the procedure, though in recent decades improvements in surgical technique, anesthesia, and critical care have led to an increase in these operations.<sup>7</sup> These surgical interventions have been successful in lessening the significant burden of pain and disability faced by these patients<sup>8</sup>; However, ASD surgery remains complex, with rates of complications ranging from 34% to 75%.<sup>4,9-14</sup>

Obesity is an epidemic in the United States, with the Centers for Disease Control estimating the prevalence of obesity to be 39.8% in 2016.<sup>15</sup> Within spinal surgery, the impact of obesity on outcomes is controversial. Some studies have shown a correlation between obesity and longer operation times, higher rates of surgical site infection, higher rates of blood loss, increased venous thromboembolism risk, and postoperative complications.<sup>16,17</sup> Other authors report no differences between obese patients and their control counterparts in terms of postoperative complications or morbidity.<sup>18-20</sup> Finally, one study did find an increase in postoperative complications but, nonetheless, came to the conclusion that the ultimate benefits of surgery for these patients outweigh the increased risk because of an overall increase in health-related quality of life.<sup>5</sup> Most studies analyzing outcomes between obese and control patients have been within select pathologies.<sup>21</sup> Here, we investigate complications and health care costs associated with obese and control patients undergoing thoracolumbar spinal deformity surgery.

The aim of this study is to utilize a large data set to compare complications and costs following thoracolumbar spinal deformity surgery in obese patients and a control group.

## Methods

### Data Source

This study obtained a sample of the MarketScan Commercial Claims and Encounters database (Truven Health Analytics, Ann Arbor, MI) from January 1, 2007, to December 31, 2016. This database is a collection of commercial inpatient, outpatient, and pharmaceutical claims of more than 75 million employees, retirees, and dependents representing a substantial portion of the US population covered by employer-sponsored insurance. MarketScan contains 53 million inpatient records, 40 million with employer-sponsored insurance, 3.7 million with Medicare Part B, and 6.8 million on Medicaid, for a total of more than 28 billion patient records. Truven Health Analytics MarketScan data sets are publicly available to researchers for a fee per year of data. The MarketScan database contains *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) and *10th Revision, Clinical Modification* (ICD-10-CM), Current Procedural Terminology (CPT), and Diagnosis Related Group (DRG) codes as well as National Drug Codes (NDC).

### Inclusion Criteria

This study identified and included 7423 patients who underwent thoracolumbar deformity surgery (CPT codes 22800, 22802, 22804, 22808, 22810, 22812, 22818, 22819, 22843, 22844, 22846, 22846, or 22847) and who had a concurrent ICD-9 diagnosis code of spinal deformity (737.xx) between 2007 and 2016. Obesity at the time of index surgery was identified by the presence of ICD-9 diagnosis codes (278.xx). Patients <18 years old or those who had ICD-9-CM codes consistent with prior history of tumor or trauma were excluded.

### Outcomes and Variables

The primary outcome of this study was an overall composite complication rate. Specific complications, length of stay, 90-day readmissions, revision rates, and costs were assessed as well. Given that ASD surgery can occur in a staged manner during a single admission, revisions were defined as the presence of an ASD surgery procedure code after discharge from initial admission. Patient-level variables, including age at diagnosis, sex, geographic region, and quality and cost metrics, were taken directly from the claims data. Complications were assessed using ICD-9-CM codes. A subgroup analysis of osteotomy type was also included.

### Analyses and Patient Involvement

The data set was queried to identify patients who underwent primary ASD surgery. Patients were then grouped according to history of obesity diagnosis, and these cohorts were mutually exclusive. To minimize the effect of potential confounding on the direct comparison of patients undergoing ASD surgery with and without obesity, a propensity score match (PSM) was utilized. A greedy nearest-neighbor algorithm was used to match patient cohorts with a 5:1 (nonobese:obese) ratio. A caliper of 0.01 was utilized in the match, and replacement of patients in the algorithm was not allowed. Baseline demographics such as age and sex, and surgical approach were input into the algorithm, leading to the matched covariates having no statistically significant differences. Student *t* tests and  $\chi^2$  tests were utilized to assess significant differences in demographic data, baseline comorbidities, postoperative complications, quality outcomes, and payments among the groups. *P* values were interpreted as significant if less than .05.

### Patient Involvement

Because this study includes only analysis of secondary deidentified data, it was not considered human subject research and received exemption from the institutional review board approval at our institution.

**Table 1.** Baseline Characteristics of Patients Undergoing Primary ASD surgery.

Variables (%)	Non-Propensity Score Matched			Propensity Score Matched		
	Nonobese, n = 6826	Obese, n = 597	P Value	Nonobese, n = 2985	Obese, n = 597	P Value
Age mean	45.5	51.4	<.0001	51.4	51.4	.9938
Female (%)	69.8	71.9	.3078	72.0	71.9	.9469
CHF (%)	1.8	5.2	<.0001	2.0	5.2	<.0001
Hypertension (%)	36.3	69.4	<.0001	44.3	69.4	<.0001
Diabetes (%)	9.3	26.8	<.0001	10.9	26.8	<.0001
Liver disease (%)	0.3	0.5	.5114	0.3	0.5	.2572
Cardiac arrhythmia (%)	6.2	9.2	.0036	6.4	9.2	.0119
MI (%)	1.1	1.5	.3072	1.3	1.5	.6969
Tobacco use (%)	9.2	13.9	.0002	10.4	13.9	.0630
Alcohol use (%)	0.9	1.7	.0668	1.2	1.7	.3528
Osteoporosis (%)	14.9	22.3	<.0001	17.4	22.3	.0050
Approach type (%)			.0222			.7562
Anterior	21.3	26.2		25.8	26.2	
Posterior	75.5	70.5		71.4	70.5	
Combined	3.2	3.4		2.8	3.4	
Osteotomy use	36.3	36.9	.8003	34.9	36.9	.3560

Abbreviations: ASD, adult spinal deformity; CHF, congestive heart failure; MI, myocardial infarction.

**Table 2.** Postoperative Complications Within 90 Days.

Variables (%)	Non-Propensity Score Matched			Propensity Score Matched		
	Nonobese, n = 6826	Obese, n = 597	P Value	Nonobese, n = 2985	Obese, n = 597	P Value
Any complication	40.8	46.1	.0115	42.4	46.1	.0938
Pulmonary complication	14.2	14.7	.6781	14.4	14.7	.8485
Posthemorrhagic anemia	27.3	32.8	.0037	28.9	32.8	.0554
Sepsis	0.9	1.8	.0301	1.1	1.8	.1356
CNS complication	1.1	2	.0383	1.2	2	.1188
Cardiac complication	1.6	1	.2519	1.8	1	.1488
Wound complication	1.7	3.5	.0014	2.1	3.5	.0327
DVT	0.8	0.5	.4582	0.9	0.5	.359
PE	1.7	2.4	.2488	2.2	2.4	.8397
Acute kidney injury	1.6	4.4	<.0001	1.7	4.4	<.0001
Hematoma	2.7	4.2	.0392	2.8	4.2	.0591

Abbreviations: CNS, central nervous system; DVT, deep-venous thrombosis; PE, pulmonary embolism.

## Results

### Patient Cohort

A total of 7423 patients met the inclusion criteria of this study, of whom 597 (8.0%) were obese. Obese patients were older (51.4 vs 45.5,  $P < .05$ ) and had a significantly higher comorbidity burden than nonobese patients. Patients with obesity had higher rates of congestive heart failure (CHF), hypertension, diabetes, and previous cardiac arrhythmias ( $P < .05$ ). Obese patients were also more frequently tobacco users (13.9% vs 9.2%,  $P < .05$ ). Posterior surgical approach was preferred in both cohorts; however, obese patients were less likely to be operated on anteriorly ( $P < .05$ ). Osteotomy use was consistent between cohorts. After PSM, there were no longer any statistically significant differences in mean age or sex ratios. Approach type was also similar between the control and obesity cohorts (Table 1).

### 90-Day Complication Rates Between Obese and Nonobese Patients

Patients with obesity had a higher 90-day postoperative complication rate than nonobese patients (46.1% vs 40.8%,  $P < .05$ ). This was primarily driven by elevated rates of posthemorrhagic anemia (32.8% vs 27.3%,  $P < .05$ ). Acute kidney injury, sepsis, central nervous system (CNS)-related complications, wound complications, and hematoma rates were also higher in obese patients.

After PSM, the overall 90-day complication rate was similar between obese and nonobese patients. The complication rate was 42.4% in the control cohort and 46.1% in the obese cohort. Only wound complications (3.5% vs 2.1%,  $P < .05$ ) and acute kidney injury rates (4.4% vs 1.7%,  $P < .05$ ) remained significantly higher in obese patients (Table 2).

**Table 3.** Quality Outcomes.

Variables (%)	Non-Propensity Score Matched			Propensity Score Matched		
	Nonobese, n = 6826	Obese, n = 597	P Value	Nonobese, n = 2985	Obese, n = 597	P Value
Length of stay	5.8	6.2	.2914	5.8	6.2	.2224
Revision surgery						
90 Days	13	13.9	.5209	14.6	13.9	.6557
6 Months	14.4	16.1	.2599	16.3	16.1	.8879
1 Year	16.6	18.1	.3439	19	18.1	.5929
2 Years	19.1	21.4	.1708	22	21.4	.7588
Readmission within 90 days	20.3	28.1	<.0001	22.6	28.1	.0032

**Table 4.** Procedure Payments.

Variables (%)	Non-Propensity Score Matched			Propensity Score Matched		
	Nonobese, n = 6826	Obese, n = 597	P Value	Nonobese, n = 2985	Obese, n = 597	P Value
Index hospitalization payments						
Physician	\$13 699	\$13 659	.9660	\$13 946	\$13 659	.7674
Hospital	\$92 540	\$96 415	.2898	\$93 789	\$96 415	.4825
Total	\$114 670	\$120 176	.2060	\$116 121	\$120 176	.3726
Total payments						
90 Days	\$122 245	\$133 056	.0219	\$124 614	\$133 056	.0868
6 Months	\$124 855	\$136 447	.0160	\$127 133	\$136 447	.0638
1 Year	\$129 499	\$142 884	.0098	\$132 504	\$142 884	.055
2 Years	\$136 554	\$152 930	.0065	\$140 550	\$152 930	.0474

### Quality and Health Care Use Outcomes

Lengths of stay were similar between obese and nonobese patients (6.2 vs 5.8 days). Revision surgery occurred at a higher rate in the obese cohort. However, the difference in rates at 90 days (13.9% vs 13.0%), 6 months (16.1% vs 14.4%), 1 year (18.1% vs 16.6%), and 2 years (21.4% vs 19.1%) following primary surgery failed to achieve statistical significance. Rates of readmission were higher in patients with obesity (28.1% vs 20.3%,  $P < .05$ ; Table 3). After PSM, length of stay and revision surgery rate remained similar between cohorts. Readmission rates remained significantly higher in the obese cohort ( $P < .05$ ).

In the non-PSM data, there were no apparent differences in immediate health care use during index hospitalization (control, \$114 670, vs obese, \$120 176;  $P = .3978$ ). However, obese patients were associated with higher payments at all time points during follow-up through 2 years ( $P < .05$ ). After PSM, the only difference in health care use occurred at long-term follow-up of 2 years (obese, \$152 930, vs nonobese, \$140 550,  $P < .05$ ; Table 4).

## Discussion

### Obesity and Postoperative Outcomes

Several prior studies have reported on the relationship between obesity and long-term outcomes and complications following ASD surgery; however, there is no clear consensus as to its impact. Studies with a positive finding include the work of Pull

ter Gunne et al,<sup>22</sup> who found an increased incidence of wound infection for obese patients, postulating that the larger amount of subcutaneous fat needed to be retracted led to more cell necrosis and, thus, higher rates of infection. Also, Soroceanu et al<sup>8</sup> found that obese patients had a higher rate of major complications and wound infections, but this did not influence the number of minor complications or the need for revision surgery.

Specifically to thoracolumbar deformities, Yadla et al<sup>20</sup> found no relationship between body mass index (BMI) and the incidence of perioperative minor or major complications. Similarly, Chen et al<sup>23</sup> found that obesity did not affect the outcome of surgical correction for coronal and sagittal scoliotic deformity, which has been affirmed by other authors.<sup>24</sup>

Our study found significant differences in postoperative complications between the obese and control cohorts. Specifically, obese patients had a higher rate of overall complications, posthemorrhagic anemia, sepsis, CNS complications, wound infections, acute kidney injury, and hematoma. Obese patients also had a higher rate of readmission than the control cohort. However, obesity is linked with higher rates of many comorbid conditions (hypertension, diabetes, CHF, osteoporosis), which our data similarly demonstrate.<sup>22,23</sup> Thus, many of these findings would largely be a result of not obesity itself but of the sequelae or comorbidities that often present with obesity: CHF, hypertension, and diabetes in this analysis.

Accordingly, our PSM-matched cohort reflected the clinical manifestations of many obese patients, containing a

significantly higher percentage of patients with CHF, hypertension, and/or diabetes. Following PSM analysis, the following variables were still significant: increased risk of wound complications, increased risk of acute kidney injury, and increased 2-year payment. Our analysis on wound complication affirms the work by Pull ter Gunne et al<sup>22</sup>: although the effects of obesity and its sequelae on acute kidney injury have not been studied thoroughly, they may be linked to the increased rate of hypertension and arteriolosclerosis in these patients.

In the literature, some studies utilized BMI as a continuous scale, and a gradual increase in back pain and disability with higher BMI could be demonstrated for patients with lumbar degenerative disc disease.<sup>21</sup> Our study and other studies stratified by obese versus nonobese. It is plausible to assume that the longer a patient has been obese, the more comorbidities they may carry, which may not be reflected in a scaled model or in a binary system. Other studies in the literature further stratify obesity into its own categories,<sup>25</sup> which may help elucidate the effects of extreme weight on surgical outcomes. Neither of these characteristics was able to be studied within our population-based data set and warrants further study.

### The Effect of Obesity on Cost

The literature on the isolated effects of obesity and cost of thoracolumbar spinal deformity surgery is sparse. Amin et al,<sup>26</sup> in their retrospective review, found that after analyzing 244 ASD patients, class II and III (BMI  $\geq 35$  kg/m<sup>2</sup>) obese patients had higher rates of “high episode-of-care costs” (>\$80 000). Stephens et al<sup>27</sup> did not find BMI to have a significant impact on cost of adult thoracolumbar spinal deformity surgery in their prospective model of 129 patients.<sup>2</sup> However, this study did not explicitly analyze the difference between an obese cohort and nonobese cohort. In our analysis, we found that obese patients paid more for their care at 90 days, 6 months, 1 year, and 2 years compared with the control cohort. However, after PSM matching, this relationship only remained statistically significant at the 2-year mark, though it approached significance at the 1-year mark. The significant increase in acute kidney disease following the ASD may contribute to this significance. Alternatively, obesity may influence other aspects of long-term management of these patients, such as tolerance to physical rehabilitation. To the authors’ knowledge, our study is the only national database analysis that explores the individual impact of obesity on total cost of adult thoracolumbar ASD surgery.

### Limitations

As with all large database studies, interpretations of this study are limited by the retrospective and administrative nature of the data.<sup>28,29</sup> We assumed accuracy of all diagnosis and procedure codes in the database. The MarketScan database aggregates data on commercially insured patients. Because patients, procedures, and clinical outcomes were queried using ICD-9-CM codes, it is not possible to assess the underlying validity of the collected records. A specific concern to this study would be the

underdiagnoses and underreporting of obesity, which may have confounded this study’s findings. Although obesity is often recorded in patient’s charts, it is not necessarily billed as a separate code, and for this reason, we may not have been able to capture the full scope of patients with obesity undergoing ASD surgery. There also may have been discrepancies in the degree of deformity between the obese and nonobese cohorts, a factor we were unable to control for. More specific data regarding BMI was also unavailable. However, these data provide novel and useful insight into the tolerability of ASD surgery in obese patients and may aid spine surgeons with patient selection.

### Conclusion

In this study, patients with obesity were at no greater risk for postoperative complication and revision surgery; however, obesity may lead to increased health care resource use. The benefits of deformity correction may outweigh the risks, but further prospective research should be conducted to establish the safety of spine surgery in obese patients.

### Declaration of Conflicting Interests

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### ORCID iD

Kunal Varshneya, BS  <https://orcid.org/0000-0003-4910-9712>  
Martin N. Stienen, MD, FEBNS  <https://orcid.org/0000-0002-6417-1787>

### References

1. Kebaish KM, Neubauer PR, Voros GD, Khoshnevisan MA, Skolasky RL. Scoliosis in adults aged forty years and older: prevalence and relationship to age, race, and gender. *Spine (Phila Pa 1976)*. 2011;36:731-736. doi:10.1097/BRS.0b013e3181e9f120
2. Francis RS. Scoliosis screening of 3000 college-aged women. The Utah Study—phase 2. *Phys Ther*. 1988;68:1513-1516.
3. Schwab F, Dubey A, Gamez L, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. *Spine (Phila Pa 1976)*. 2005;30:1082-1085. doi:00007632-200505010-00017
4. Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. *Spine (Phila Pa 1976)*. 2005;30:2024-2029. doi:10.1097/01.brs.0000179086.30449.96
5. Glassman SD, Berven S, Bridwell K, Horton W, Dimar J. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine (Phila Pa 1976)*. 2005;30:682-688. doi:10.1097/01.brs.0000155425.04536.f7

6. Schwab F, Farcy JP, Bridwell K, et al. A clinical impact classification of scoliosis in the adult. *Spine (Phila Pa 1976)*. 2006;31:2109-2114. doi:10.1097/01.brs.0000231725.38943.ab
7. Smith JS, Shaffrey CI, Ames CP, Lenke LG. Treatment of adult thoracolumbar spinal deformity: past, present, and future. *J Neurosurg Spine*. 2019;30:551-567. doi:10.3171/2019.1.SPINE.181494
8. Soroceanu A, Burton DC, Diebo BG, et al. Impact of obesity on complications, infection, and patient-reported outcomes in adult spinal deformity surgery. *J Neurosurg Spine*. 2015;23:656-664. doi:10.3171/2015.3.SPINE.14743
9. Shapiro GS, Taira G, Boachie-Adjei O. Results of surgical treatment of adult idiopathic scoliosis with low back pain and spinal stenosis: a study of long-term clinical radiographic outcomes. *Spine (Phila Pa 1976)*. 2003;28:358-363. doi:10.1097/01.BRS.0000048502.62793.0C
10. Bhagat S, Vozar V, Lutchman L, Crawford RJ, Rai AS. Morbidity and mortality in adult spinal deformity surgery: Norwich Spinal Unit experience. *Eur Spine J*. 2013;22(suppl 1):S42-S46. doi:10.1007/s00586-012-2627-y
11. Cho SK, Bridwell KH, Lenke LG, et al. Major complications in revision adult deformity surgery: risk factors and clinical outcomes with 2- to 7-year follow-up. *Spine (Phila Pa 1976)*. 2012;37:489-500. doi:10.1097/BRS.0b013e3182217ab5
12. DeWald CJ, Stanley T. Instrumentation-related complications of multilevel fusions for adult spinal deformity patients over age 65: surgical considerations and treatment options in patients with poor bone quality. *Spine (Phila Pa 1976)*. 2006;31(19, suppl):S144-S151. doi:10.1097/01.brs.0000236893.65878.39
13. Lonergan T, Place H, Taylor P. Acute complications after adult spinal deformity surgery in patients aged 70 years and older. *Clin Spine Surg*. 2016;29:314-317. doi:10.1097/BSJ.0b013e3182764a23
14. Smith JS, Shaffrey CI, Berven S, et al. Operative versus nonoperative treatment of leg pain in adults with scoliosis: a retrospective review of a prospective multicenter database with two-year follow-up. *Spine (Phila Pa 1976)*. 2009;34:1693-1698. doi:10.1097/BRS.0b013e3181ac5fcd
15. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311:806-814. doi:10.1001/jama.2014.732
16. Marquez-Lara A, Nandyala SV, Sankaranarayanan S, Noureldin M, Singh K. Body mass index as a predictor of complications and mortality after lumbar spine surgery. *Spine (Phila Pa 1976)*. 2014;39:798-804. doi:10.1097/BRS.0000000000000232
17. Cao J, Kong L, Meng F, Zhang Y, Shen Y. Impact of obesity on lumbar spinal surgery outcomes. *J Clin Neurosci*. 2016;28:1-6. doi:10.1016/j.jocn.2015.10.034
18. Park P, Upadhyaya C, Garton HJ, Foley KT. The impact of minimally invasive spine surgery on perioperative complications in overweight or obese patients. *Neurosurgery*. 2008;62:693-699. doi:10.1227/01.neu.0000317318.33365.fl
19. Srinivasan D, La Marca F, Than KD, Patel RD, Park P. Perioperative characteristics and complications in obese patients undergoing anterior cervical fusion surgery. *J Clin Neurosci*. 2014;21:1159-1162. doi:10.1016/j.jocn.2013.11.017
20. Yadla S, Malone J, Campbell PG, et al. Obesity and spine surgery: reassessment based on a prospective evaluation of perioperative complications in elective degenerative thoracolumbar procedures. *Spine J*. 2010;10:581-587. doi:10.1016/j.spinee.2010.03.001
21. Stienen MN, Joswig H, Smoll NR, et al. Influence of body mass index on subjective and objective measures of pain, functional impairment, and health-related quality of life in lumbar degenerative disc disease. *World Neurosurg*. 2016;96:57-577.e1. doi:10.1016/j.wneu.2016.09.070
22. Pull ter Gunne AF, van Laarhoven CJ, Cohen DB. Incidence of surgical site infection following adult spinal deformity surgery: an analysis of patient risk. *Eur Spine J*. 2010;19:982-988. doi:10.1007/s00586-009-1269-1
23. Chen Z, Yi H, Li M, et al. Associations between body mass and the outcome of surgery for scoliosis in Chinese adults. *PLoS One*. 2011;6:e21601. doi:10.1371/journal.pone.0021601
24. Fu L, Chang MS, Crandall DG, Revella J. Does obesity affect surgical outcomes in degenerative scoliosis? *Spine (Phila Pa 1976)*. 2014;39:2049-2055. doi:10.1097/BRS.000000000000000600
25. Seicean A, Alan N, Seicean S, et al. Impact of increased body mass index on outcomes of elective spinal surgery. *Spine (Phila Pa 1976)*. 2014;39:1520-1530. doi:10.1097/BRS.0000000000000435
26. Amin RM, Raad M, Jain A, Sandhu KP, Frank SM, Kebaish KM. Increasing body mass index is associated with worse perioperative outcomes and higher costs in adult spinal deformity surgery. *Spine (Phila Pa 1976)*. 2018;43:693-698. doi:10.1097/BRS.00000000000002407
27. Stephens BF II, Khan I, Chotai S, Sivaganesan A, Devin CJ. Drivers of cost in adult thoracolumbar spine deformity surgery. *World Neurosurg*. 2018;118:e206-e211. doi:10.1016/j.wneu.2018.08.018
28. Varshneya K, Azad TD, Pendharkar AV, et al. Adult spinal deformity surgery in patients with movement disorders—a propensity matched analysis of outcomes and cost [published online September 13, 2019]. *Spine (Phila Pa 1976)*. doi:10.1097/brs.00000000000003251
29. Varshneya K, Medress ZA, Jensen M, et al. Trends in anterior lumbar interbody fusion in the United States: a MarketScan Study from 2007 to 2014 [published online October 10, 2019]. *Clin Spine Surg*. doi:10.1097/bsd.0000000000000904